Analysis of Alternatives: Deriving Warfighter Utility From Functional Measures of System-of-Systems Performance

Dr. Paul H. Deitz, Technical Director

U.S. Army Materiel Systems Analysis Activity
ATTN: AMXSY-TD
Aberdeen Proving Ground, MD 21005-5071
(410) 278-6598, DSN 298-6598;phd@arl.mil
http://amsaa-web.arl.mil/OTD/techdir.html

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Workshop Issues

- Planning “optimum” tests
- Planning best mix of testing and modeling for evaluation
- Realistic “stimulation” of platforms under test
- Methods of cost control in T&E
- Economic models for T&E
- Cost effectiveness comparisons of T&E facilities

Workshop Issues (cont)

None of these objectives has meaning without appropriate:

- **Measures-of-Performance (MoP), or**
- **Measures-of-Effectiveness (MoE), or**
- **Benefit, or**
- **other relevant <u>value</u> metric(s).**

Objective of Paper

- To present a kind of operational architecture suitable for integrated weapons analysis
- To see how the elements change as a mission progresses
- To see how the structure must be built from the desired mission outcome back towards platform design
- To extend the process to a system-of-systems

Key Metrics

There are three principal weapons platform metrics:

Level 4], *Platform Utility,* which is derived from

Level 3], *Platform Capability,* which is derived from

Level 2], *Platform Componentry/Connectivity,* which is the fundamental platform metric

Key Platform Metrics

These metrics are the

WHY (Level 4])

the

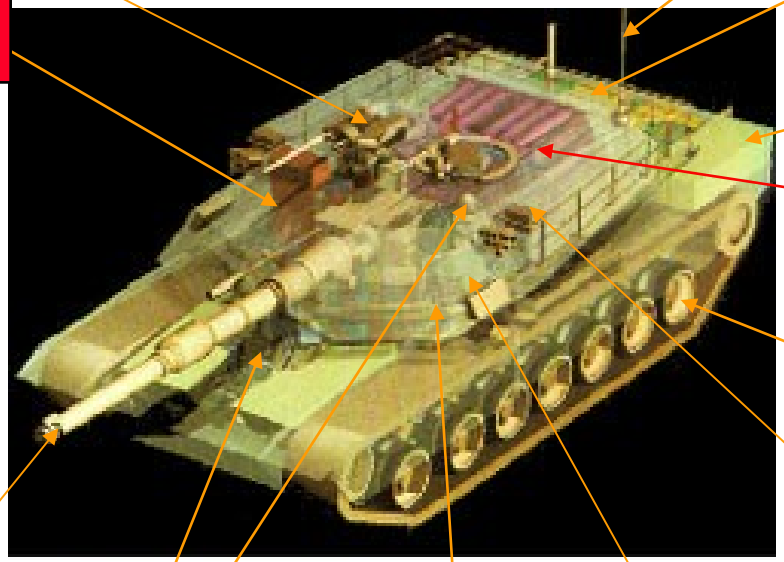
WHAT (Level 3])

and the

HOW (Level 2])

of an *operations research* framework.

Example: Platform Configuration [Level 2]



Secondary Armament

Early Warning Sensors (LWR, RWR, MWR)

Commo Equipment

Engine Compartment

Fuel

Ammo Compartment

Wheels/Track

Move

Shoot

Communicate

Commo Equipment

Target Acquisition/Engagement Sights

Main Armament

Crew

Millimeter Wave Radar Antenna

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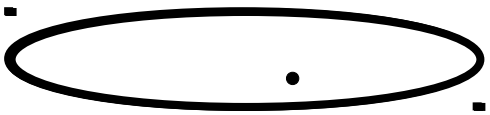
Abstraction: Platform Configuration

Level 2]

Military Operations Context

- Tactics
- Doctrine
- Scenario
- etc. (Global Variables)

Level 2] 

$v_2[C_1, C_2, \ldots, C_c, C_d, \ldots, C_i, C_k, \ldots, C_m, C_n]$

Crew Ammo Fuel Msn Crit

Re-Armed and Re-Fueled

H + 7

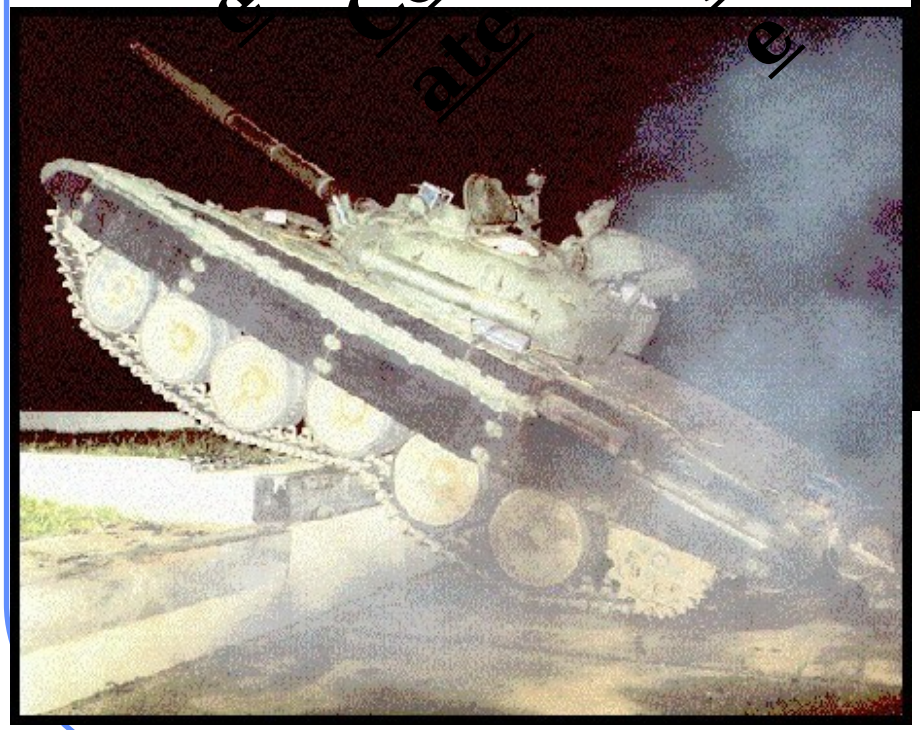
Testing for Platform Capabilities

Level 3]

Move

Communicate

Sense



Engage

Replenish

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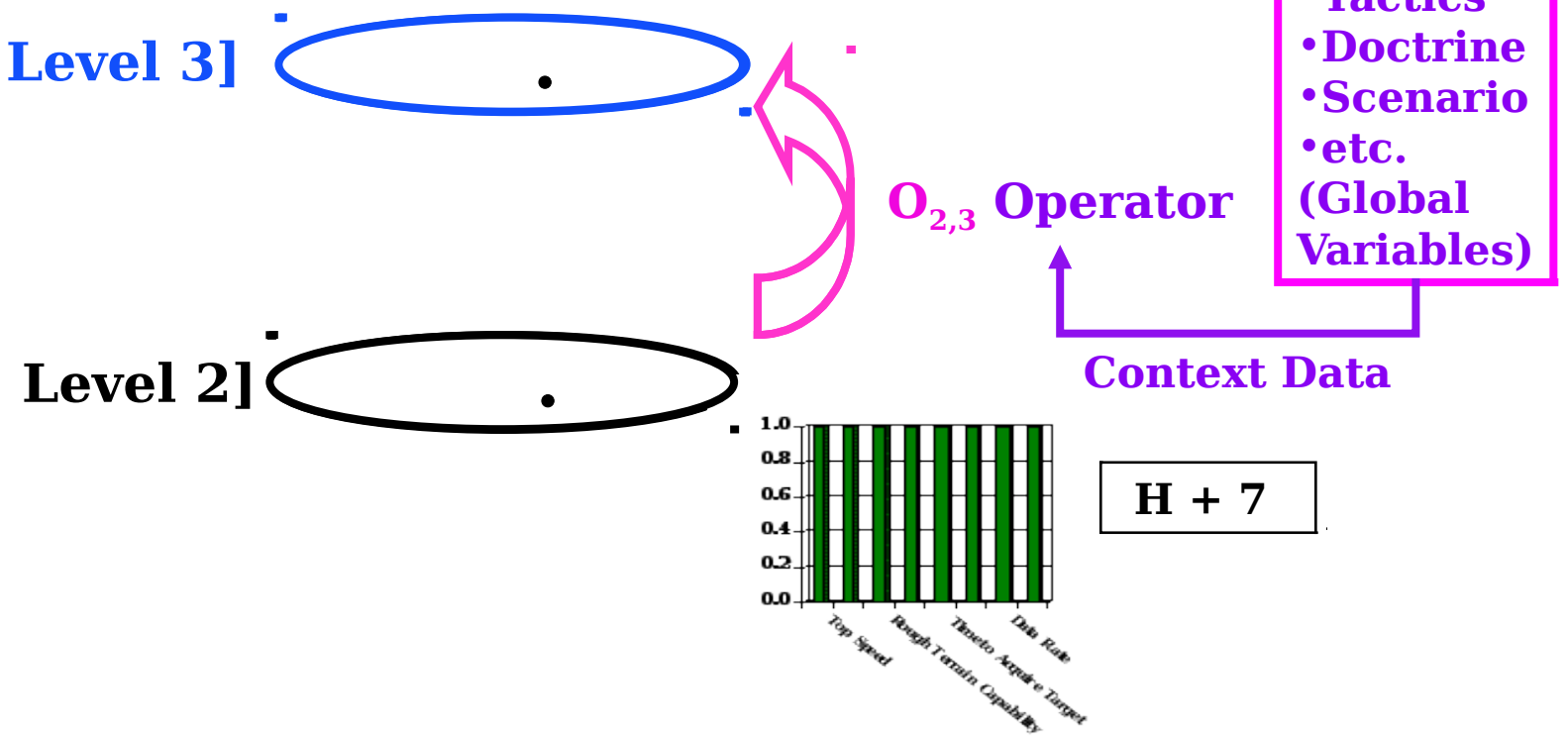
Abstraction: Platform Capabilities [Level 3]

v_3[Top Speed, Max Range, Rough Terrain C[illegible]ability, ... litary
Rate of Fire, Time to Acquire Tgt, Hit D[illegible]spersion, ... eratio
Data Rate, Data Latency, ...]



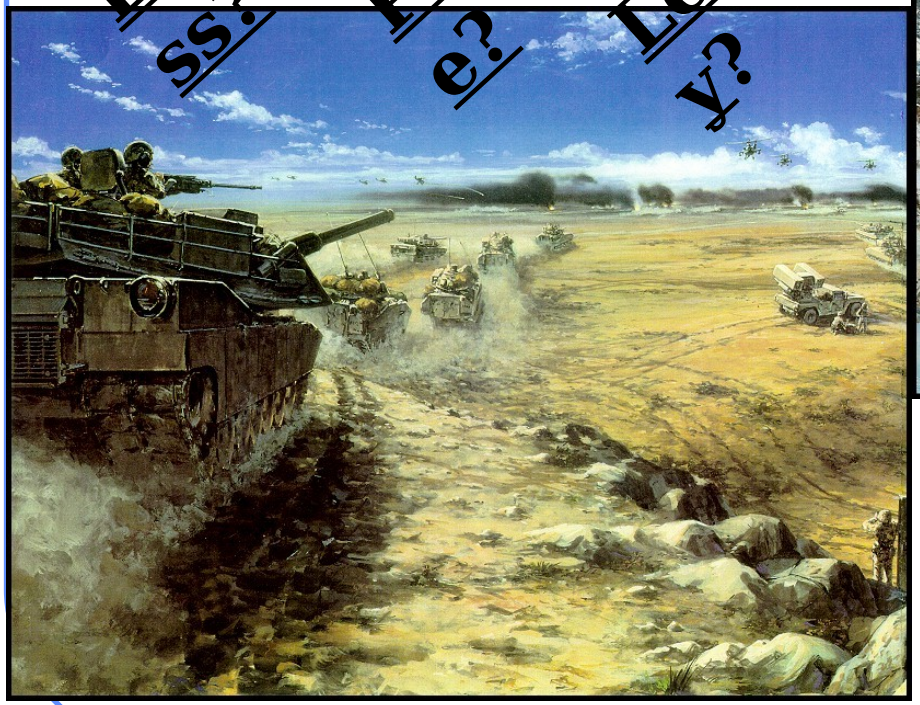
Mission Utility from Capabilities

Level 4]

Effectiveness?

Performance?

Lethality?



Survivability?

Loss/Exchang

Readiness?

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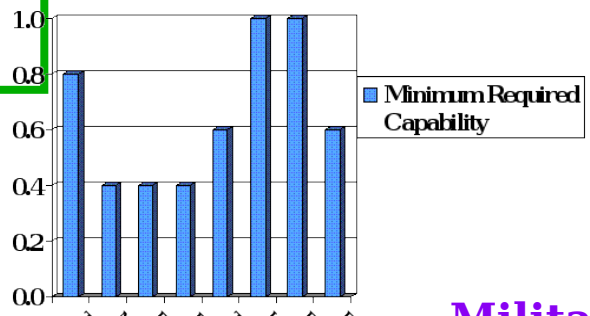
Abstraction: Platform Utility

Level 4]



Level 4]

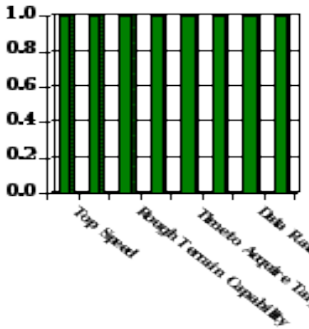
$O_{3,4}$ Operator

Msn Cap Reqs

Military Operations Context

- Tactics
- Doctrine
- Scenario
- etc.

(Global Variables)



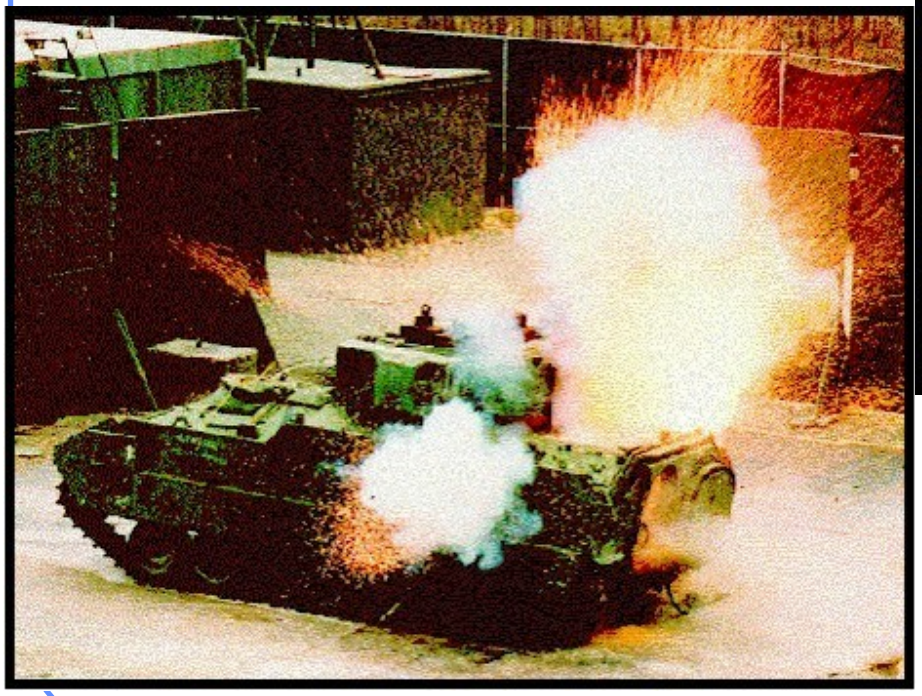
H + 7

$O_{2,3}$ Operator

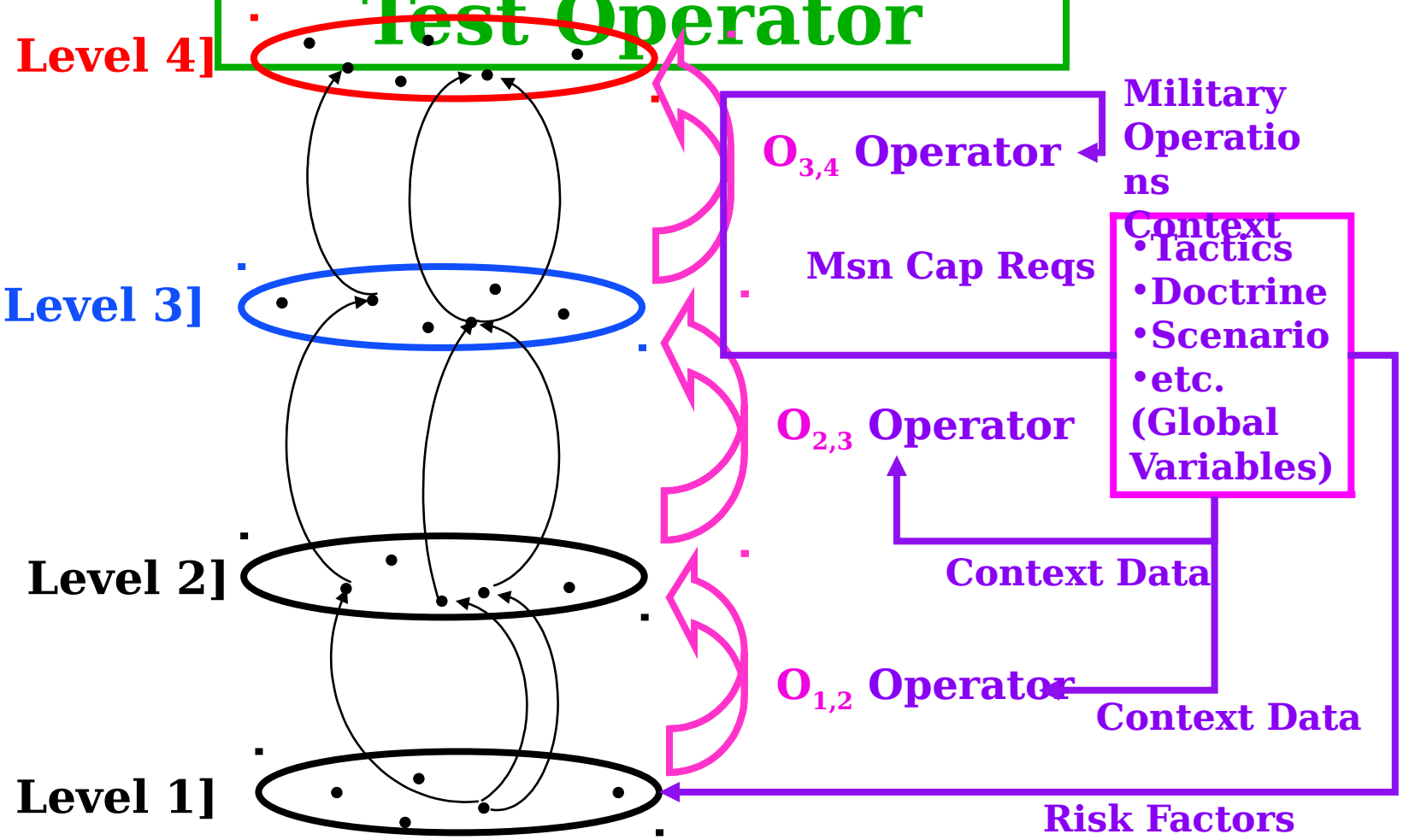
Level 2]

Context Data

Physical Analogues for the $O_{1,2}$ Operator



Abstraction: Platform Live-Fire Test Operator



Level 4] - Mission Outcomes Status

Ablaze, the Arizona slips beneath the water

More US Marines won the Medal of Honor on Iwo Jima than in any other battle in US History.

In 36 days of fighting there were **25,851 US casualties** (1 in 3 were killed or wounded).

Virtually all 22,000 Japanese perished.

Measure? Avoidance?

Loss Exchange Ratio (LER)

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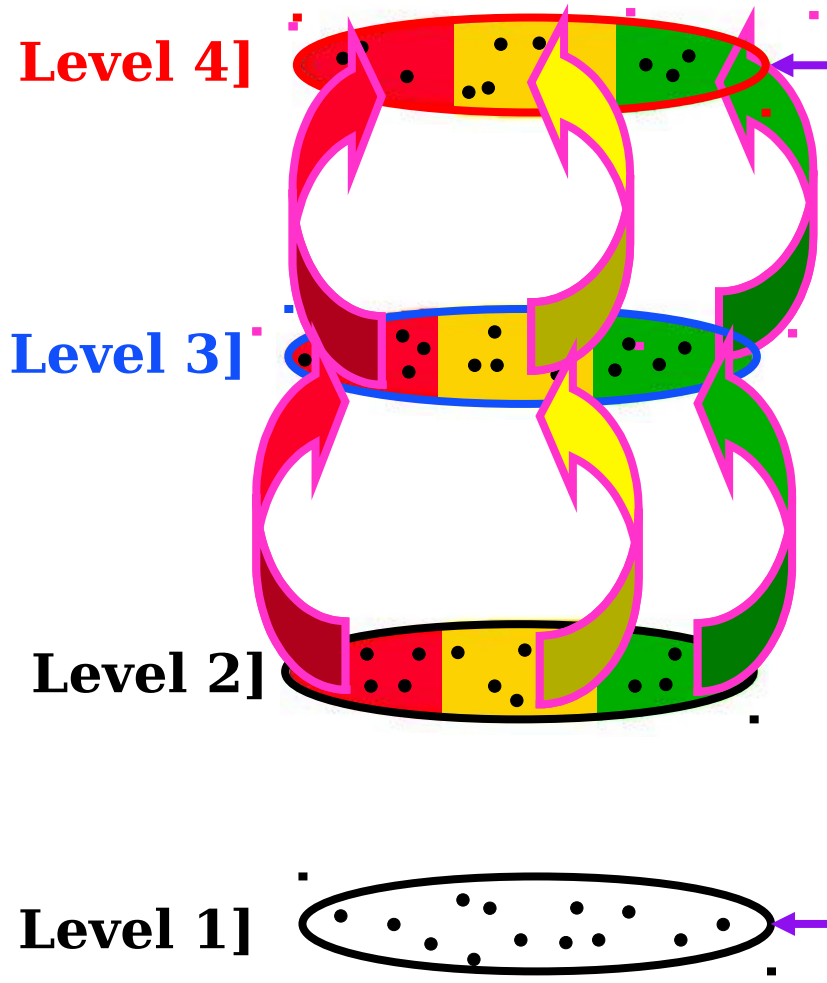
Mission-Based Utility



Mission Effectiveness

Military Operations Context

$O_{3,4}$ Operator

Msn Cap Reqs

- Tactics
- Doctrine
- Scenario
- etc.

(Global Variables)

$O_{2,3}$ Operator

Context Data

$O_{1,2}$ Operator

Context Data

Risk Factors

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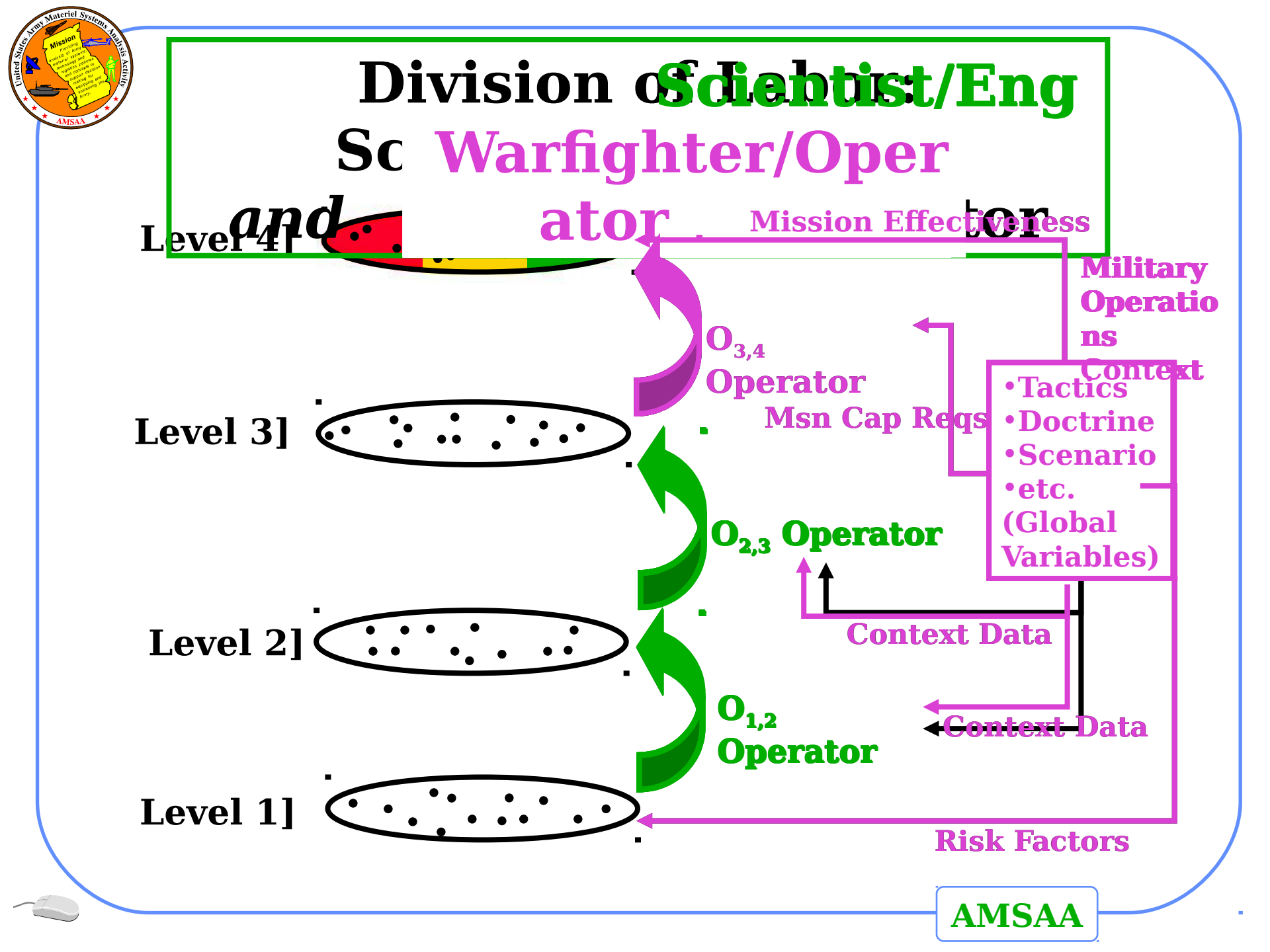
Division of Labor:
Scientist/Eng
Warfighter/Operator
and
Level 4]
Level 3]
Level 2]
Level 1]
Mission Effectiveness
Military Operations Context
$O_{3,4}$ Operator
Msn Cap Reqs
•Tactics
•Doctrine
•Scenario
•etc.
(Global Variables)
$O_{2,3}$ Operator
Context Data
$O_{1,2}$ Operator
Context Data
Risk Factors
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Summary

- **Have described an analysis framework that:**
  - **has three linked metrics – utility, capability, componentry**
  - **where utility is based on mission-related capabilities**
  - **capabilities are based on componentry**
  - **platform componentry is the <u>fundamental metric</u>, and**
  - **the linkages include dependencies on specific military mission/context**
- **Platform effectiveness can change with time as:**
  - **a] mission requirements change, and/or**
  - **b] the component infrastructure degrades/is reconstituted**

Summary (cont)

- **What you as testers <u>can measure</u> is:**
  a] the effect of the military environment (*e.g.* bullets, wear out, resupply) on platform component parts and
  b] the performance (*e.g.* move, shoot, communicate) of the platform as a whole in the military environment.
- **What you as testers <u>cannot measure</u> is platform military effectiveness, and must seek the warfighter input to infer:**
  a] how performance forms the basis for effectiveness and
  b] what defines the military environment(s).

Summary (cont)

- Process also implies that you must begin by defining:
  1] what constitutes operational effectiveness, then
  2] the key supporting capabilities, and then
  3] the robustness of the key components which support those capabilities.
- Process implies a clear division of labor between the Scientist/ Engineer and the Warfighter/Operator, and who has the appropriate knowledge for each piece of the process.
- The following paper by Mr. Sheehan describes a method for developing the relationship between platform performance and military effectiveness.

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Backups

References

- P. H. Deitz, *A V/L Taxonomy for Analyzing Ballistic Live-Fire Events*, **Proceedings of the 46th Annual Bomb & Warhead Technical Symposium**, 13-15 May 1996, Monterey, CA; also US Army Research Laboratory Technical Report ARL-TR-1274, December 1996.
- P. H. Deitz and M. W. Starks, *The Generation, Use, and Misuse of 'PKs' in Vulnerability/Lethality Analyses*, **The Journal of Military Operations Research**, **Vol. 4**, No. 1, 1999.
- F. Haddix, *The Conceptual Models of the Mission Space (CMMS) Data Representation and Interchange Specification*, **Proceedings of the 1999 Fall Simulation Interoperability Workshop**, sponsored by the Simulation Interoperability Standards Organization, September 1999.
- R. Luman, *Upgrading Complex Systems of Systems: A CAIV Methodology for Warfare Area Requirements Allocation*, **66th Military Operations Research Society Symposium**, Working Group 26, 24 June 1998.
- E. L. DuBois, W. P. Hughes, and L.J. Low, *A Concise Theory of Combat*, **Institute for Joint Warfare Analysis**, Naval Postgraduate School, 1999.
- P. H. Deitz, *Parsing SMART: What Are the Pieces and How Do They Fit Together?*, **Proceedings of the 1999 Fall Simulation**

Component Change Mechanisms

(Quasi-) Perm Damage	Temp Damage	Comp Repair/Fi
Ballistic	Electronic Jamming	Battle Damage
Chemical	Cosite Interference	Resupply/Replenish
Laser		Sleep+
Directed Energy		
High-Pwr Laser		
Nuclear		
Physics of Failure		
Logistics Burdens (Fuel, Ammo)		
Reliability		
Fair Wear & Tear		
Fatigue+		
Heat Stress+		

+ Personnel Related

Combined Platform Performance

ACQUIRE

ACQUIRE

ACQUIRE

COMMO

H + 5

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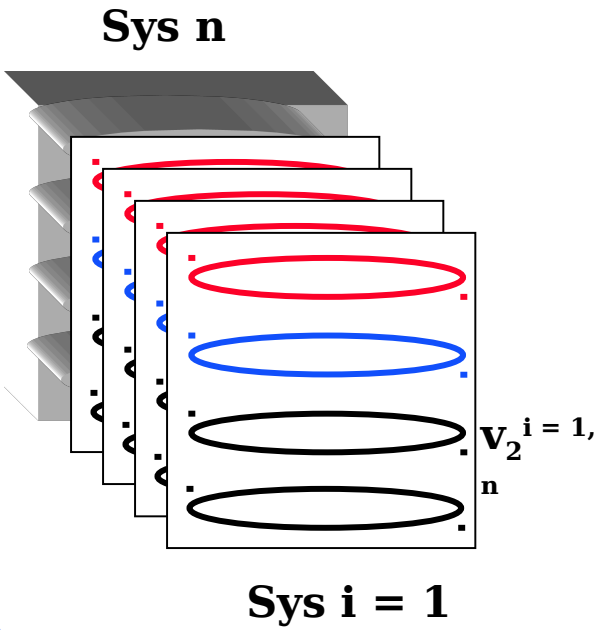
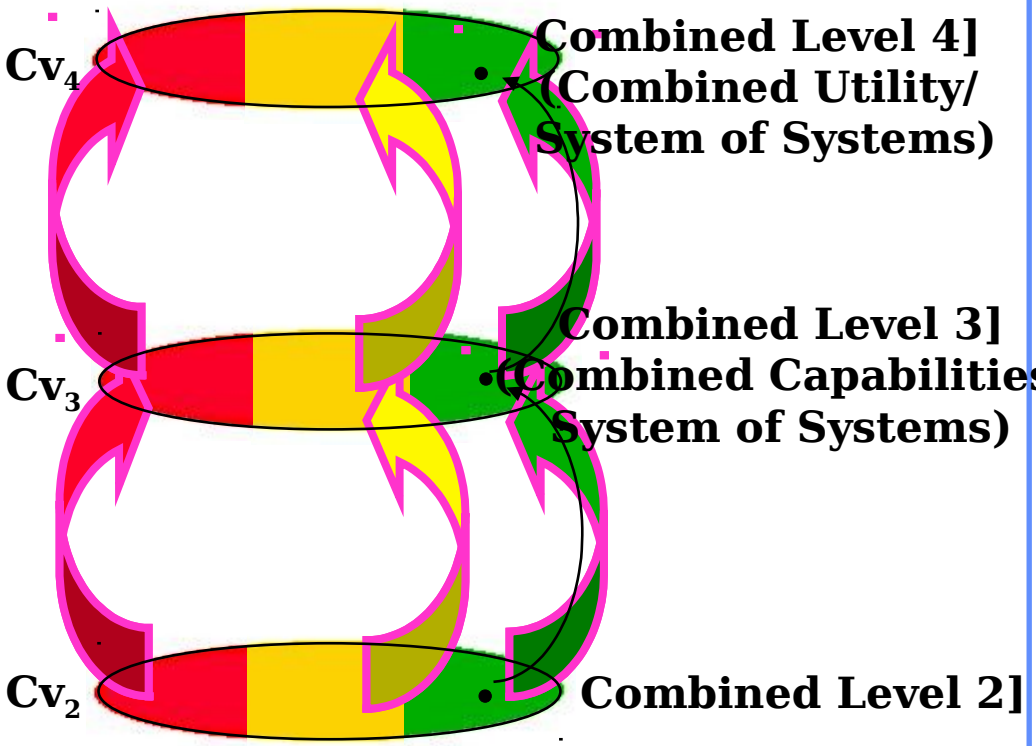
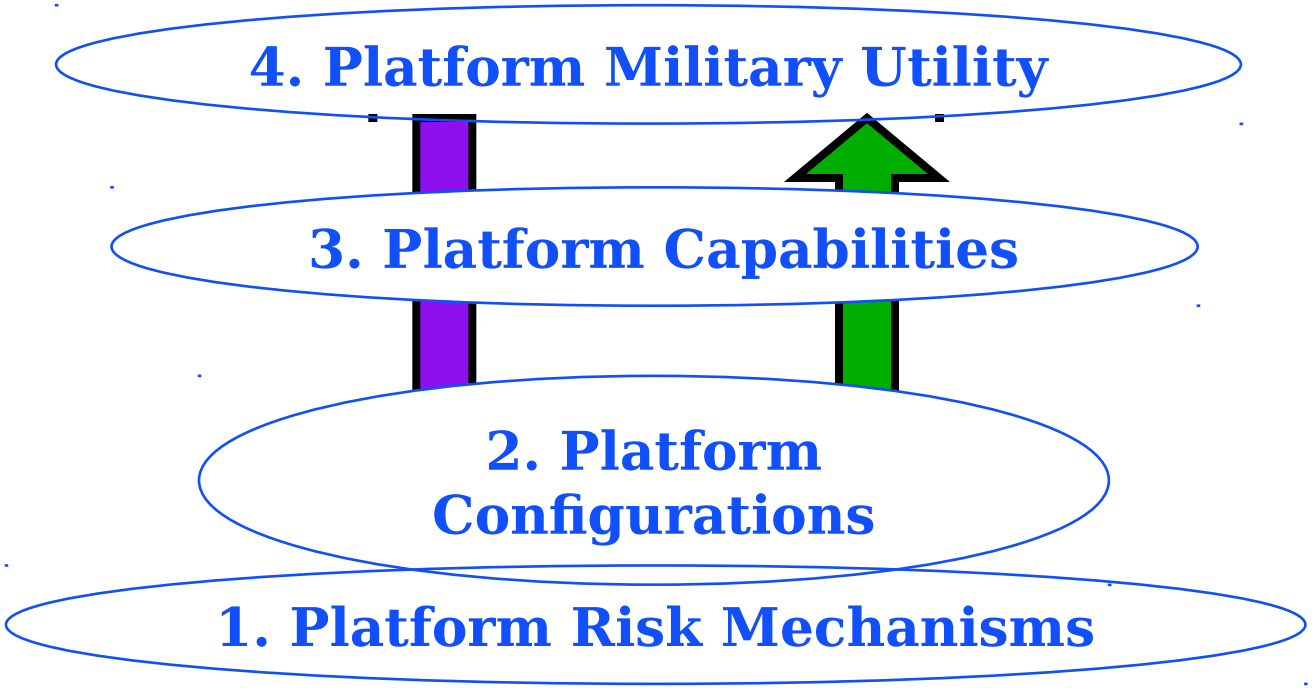
System-of-Systems



$V_2^{i=1,n}$



Top-Down Decompositional Framework

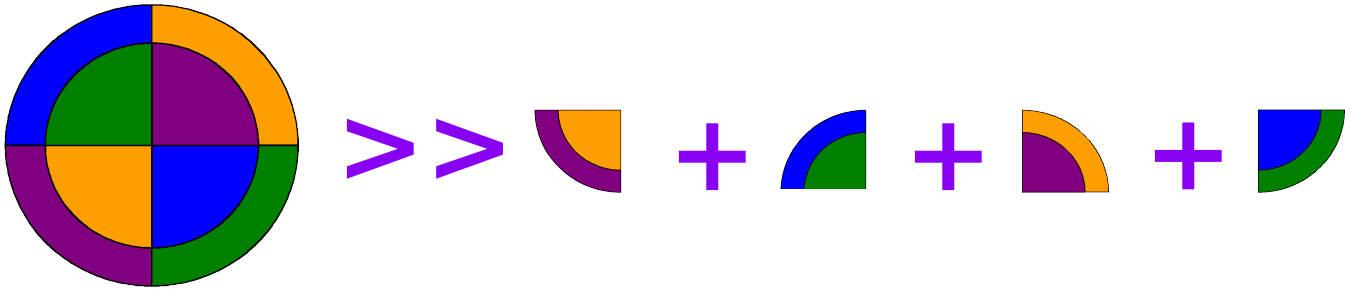


Bottom-Up Analysis Framework

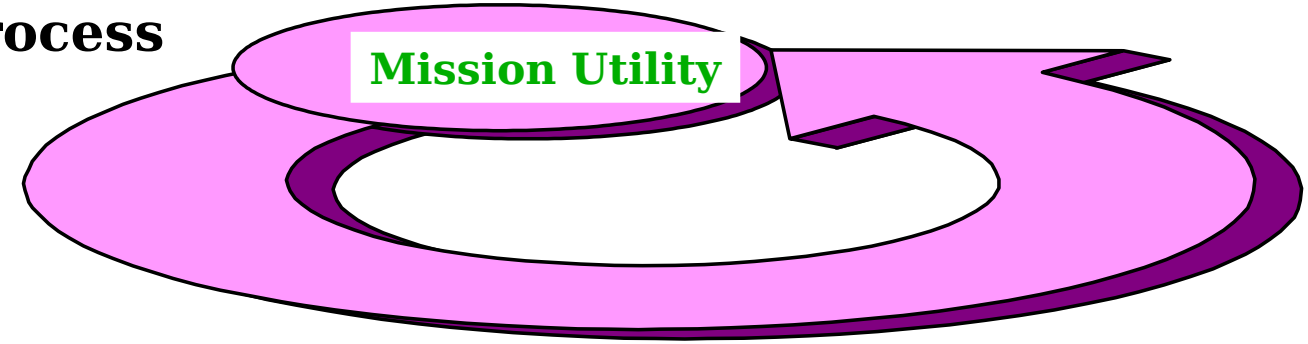
Bottom-up process follows causal (*i.e.*, time-forward) behavior

Conclusions

- **With an instantiated environment -**



- **Process**



- **Mission Utility**

Platform Technology

- **Applicable to "Systems-of-Systems" *e.g.***

<u>Communication Systems</u>

- **Provides structure for C/B, CAIV, and AoA analyses**